Defining a Fire Ending Event in the Caribou Wilderness Lassen National Forest

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Technical Fire Management IX

CONE LAKE
CONE LAKE TRAILHEAD
6 MILES TO BOGARD AND HWY 44
BLACK BUTTE
WIDOW LAKE
LASSEN VOLCANIC NATIONAL PARK
TRIANGLE LAKE
CARIBOU PEAK
F.S. 10
TWIN LKS.
PINE L.
TURNAROUND LAKE
ELEANOR L.
CARIBOU LAKE TRAILHEAD
CARIBOU LAKE
TO A-21
BLACK LAKE
JEWELL L.
GEM LAKE
EMERALD LAKE
SILVER L.
RED CINDER CONE 8,008'
RED CINDER 8,375'
N. DIVIDE LAKE
S. DIVIDE L.
RIM L.
BETTY LAKE
CYPRESS
NORTH CARIBOU 7,793'
TRAIL LAKE
SOUTH CARIBOU 7,767'
LINDSAY LAKE
LONG LAKE
POSEY LAKE
BLACK CINDER ROCK 7,758'
BEAUTY L.
HIDDEN LAKES
EVELYN L.
TO SILVER LAKE
BOOFISH
ECHO LAKE
HAY MEADOWS TRAILHEAD
F.S. 10
14 MILES TO CHESTER

N

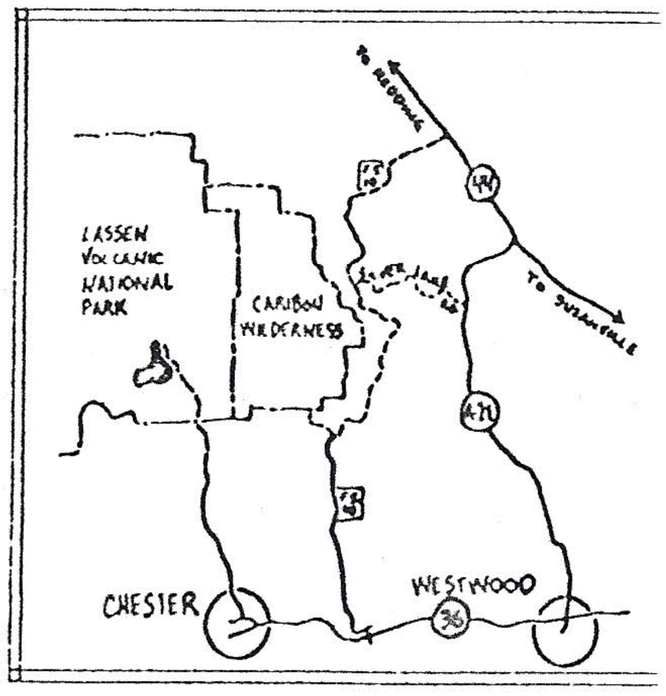
LEGEND

WILDERNESS BOUNDRY
MAINTAINED TRAILS
DIRT ROADS
PROMINENT PEAKS
CAMPGROUND
LAKES

SCALE
3 MILES

Caribou Area

Map 1



Executive Summary

The Caribou Wilderness is managed under a prescribed natural fire plan that allows natural caused fires to burn as long as certain conditions are met. To assess the risk a prescribed natural fire poses to resources inside or outside the Wilderness some estimation is needed of how far the fire will spread before some weather event halts fire spread for the remainder of the season. Weather events previously used are fixed rainfall amounts or the National Fire Danger Rating System Energy Release Component. These fire ending event estimators are reasonable assumptions but have not been analyzed to determine their reliability to estimate when no further fire spread would occur in the Caribou Wilderness.

No weather station accurately reflects the weather in the Caribou Wilderness. A portable RAWS station was set up near the Wilderness boundary during 1995. Twenty-five years of weather was approximated by comparing the daily observations from the RAWS station to the observations at two nearby permanent weather stations -- Almanor and Bogard. Mathematical regressions between daily weather observations showed Almanor was a better fit to the Wilderness observations. Using the results of the mathematical regressions Almanor weather records from 1970 to 1994 were converted to the approximated Caribou weather records.

The National Fire Danger Rating System indices and computed fuel moistures were analyzed and compared to estimated fire spread from Rothermal's spread model. The best indicator of estimating when a fire would have no further spread is a combination of rainfall amount and rainfall duration.

The dates the indicated rainfall occurred in the past were obtained from weather records from the Almanor Ranger Station. By using these dates a probability distribution was created. The charts and graph of the probability distribution can be used to give a probability of when sufficient rainfall will occur to halt the spread of a prescribed natural fire in the Caribou Wilderness.

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Problem Statement

The Caribou Wilderness, along with the adjacent Lassen Volcanic National Park is managed under a Prescribed Natural Fire Management Plan that allows natural fire ignitions to burn as long as certain conditions are met. Part of the analysis process involves assessing the risk that a fire will exceed a certain Maximum Allowable Perimeter (MAP) and threaten either public safety or resources outside the Prescribed Natural Fire Zone.

One model for assessing this risk is a program for personal computers called RERAP (*Rare Event Risk Assessment Process*) (Wiitala and Carlton, 1995) A key factor into this process is estimating when a fire will stop spreading due to the onset of some fire ending event. A fire ending event is defined here as weather after which a fire is unlikely to have any further perimeter growth. Large fuels may continue to burnout in the interior of the burned area. Rothermal (1993) used a rainfall amount of 0.5 inch over five days as a fire ending event in his preliminary paper on the subject. For the Thousand Lakes Wilderness, Lassen National Forest; Larry Hood used a variable amount of rainfall depending on the month of the year (Hood, 1995). Wiitala, Robertson and Bahr (unpub.) suggest using the date the Energy Release Component of the National Fire Danger Rating System reaches zero. This paper will explore each of these, along with other possibilities, to determine which indicator would best estimate when a fire in the Caribou Wilderness would not have any further fire spread.

Present methods of determining what constitutes a fire ending event are polling local experienced fire managers and using the Energy Release Component. The first method is highly subjective and the second method may not be an accurate indicator for all locations. Site specific criteria for a fire ending event need to be determined for the Caribou Wilderness, Lassen National Forest.

Goal

Determine what easily observed weather criteria is a reliable indicator of a fire ending event.

Objectives

Identify fuel moisture contents or other indicators that will halt fire spread for the season for a prescribed natural fire in the Caribou Wilderness.

Determine the weather observations at a permanent weather station that would most likely indicate the above determined moisture contents or indicators have occurred.

Methods

Compare the historical records from the Bogard and Almanor weather stations with the site specific 1995 Silver Lake RAWS records. Validate the RAWS data to the data from the permanent stations. Select the station with the best fit.

Analyze the historical data to determine when the Burning Index, Spread Component, or Energy Release Component drop and remain near zero for the remainder of the season. Use the observed weather on the low index days to verify little or no spread would occur.

Determine the combinations of precipitation duration and amount, or other weather, that resulted in the indices remaining low for the season. Using the weather records for individual years, determine the date(s) these events first occur each season.

Few prescribed natural fires in the Caribou/Lassen Park area have occurred since the PNF Plan implementation so historical corroboration may be difficult.

Description of the Area

The Caribou Wilderness lies in Lassen National Forest in northeast California. (Map 1) The Wilderness is roughly rectangular in shape approximately eight miles long north to south and four miles wide east to west. The Wilderness lies mostly in Lassen County, California. Boundaries of the Caribou Wilderness are not distinct topographical features such as ridgetops, but are mostly legal section lines with the west boundary of the Wilderness being the eastern boundary of Lassen Volcanic National Park. Small additions to the Caribou Wilderness in 1984 expanded portions of the east boundary to the edges of existing hiking trails. Total acreage is currently 21,440 with no private land or mining claims within the external boundary.

The boundary of the Prescribed Natural Fire Zone (PNF)[1] is not the Wilderness boundary but a line inside the Wilderness mostly along trails or features where fire tactics can be employed to prevent a fire from spreading outside the PNF Zone. (Map 2) The PNF Zone intentionally excludes the watershed of Pine Creek, which drains into Eagle Lake and is a spawning stream of Eagle Lake Trout, a rare variety of Rainbow Trout. A buffer of almost a mile in width exists along the eastern boundary near Silver Lake. The Silver Lake area is heavily used by recreationists and contains two Forest Service campgrounds and numerous summer cabins. South of Silver Lake the PNF Zone turns southwest towards Long Lake. Due to a lack of suitable topographic features in this area the line extends through an area of continuous fuel on both sides.

Geology of the Area

The Caribou Wilderness lies near the southern terminus of the Cascade Range. The origin of the area lies in the tectonic violence of the Holocene epoch. The area consists of an incised basaltic plateau with many remnant cinder cones. Soils are primarily volcanic sediments deposited during the Quaternary and Tertiary periods. Soils in the central part of the Wilderness are Xeric Durandepts with a low Available Water Capacity (AWC) of 4.0. The highland areas along the east side are Patio family soils interspersed with barren rock outcrops. These areas are low productivity sites with very low AWC of 2.3. Numerous lakes in the Wilderness were formed by impoundment by moraines during the last glaciation.

Topographically the center of the Wilderness is best described as a gentle valley running north-south formed by a series of peaks or highlands roughly along the west and east boundaries. The highest elevation is 8,370 feet MSL at Red Cinder and the lowest elevation is 6,380 in a small creek bottom along the southern boundary. The lowest elevation inside the PNF Zone is 6,620. The average elevation is 6,900.

[1] Adjacent to Lassen National Forest lies Plumas National Forest. The Plumas National Forest has been assigned the Incident Command System agency identifier of PNF. Two identical acronyms used so geographically close to each other has created confusion in the past.

The northern part of the Caribou Wilderness is drained by Pine Creek, a tributary of Eagle Lake. To the east (Silver Lake) are the headwaters of the Susan River which runs through Susanville and eventually into Honey Lake. The south is drained by Bailey Creek into Lake Almanor where it eventually becomes part of the California Water Project.

Vegetation Types

Forest types in the Caribou Wilderness are mostly sub-alpine. Extensive stands of pure Lodgepole Pine, Lodgepole-Red Fir, or Red Fir-Western White Pine predominate. There are few pure stands of Red Fir. (Map 3) Along the edges of the Wilderness areas of Mixed Conifer, White Fir, and Jeffrey Pine can be found. A large area on Red Cinder has a pure stand of Mountain Hemlock, found elsewhere in the Caribou Wilderness only in small widely scattered stands. Solem (1995) reported stands of Lodgepole Pine in the Wilderness that appeared to be serotinous. The variety of Lodgepole Pine typically found in the Caribou area is *Pinus contorta var. murrayana* and is non-serotinous (Agee, 1993). Whether this is an isolated remnant population of the serotinous variety *Pinus c. latifolia* or a genetic anomaly of *murrayana* has not been determined.

Two distinct vegetative patterns occur in the Wilderness. The north half is much drier with xeric ground cover including Squawcarpet (*Ceanothus prostratus*) and Rabbitbrush (*Chrysothamnus spp.*). Pockets of Sagebrush occur in the northeastern most corner. The timber is sparse with only scattered dense stands. The south half has more dense understory vegetation including Pinemat Manzanita (*Arctostaphylos nevadensis*) and Snowbrush (*Ceanothus velutinus*). The timber is more continuous and contains more blowdown and natural slash. These two vegetative regimes are most likely influenced by the soils and precipitation patterns. As mentioned above the Patio soils in the north half have low water capacity and are shallow and of low productivity. The soils in the southern portion, although still of low productivity and moisture content, support greater vegetative growth. The southern half of the Wilderness receives approximately ten inches more annual precipitation than the northern (Map 4).

Wildlife

With all the open water the major wildlife specie is the mosquito. The larger lakes are aerially planted with trout by the California Dept. of Fish and Game. The Bufflehead, an uncommon breeder in California, nests in the smaller lakes. Bald Eagles feed at the lakes but no nesting sites are known. Black Bear, marten and possibly fisher and wolverines inhabit the area. Deer are occasionally seen but apparently do not use the area as summer browse.

Fire History

The pre-settlement natural fire rotation in the north half of the Caribou ranges from 57 years to 195 years in the Lodgepole/Red Fir Forest type, varying by elevation and topography (Taylor, 1995). Fire return intervals were estimated at 35 years. Median fire size was determined to be 250 acres. A fire of 2,635 acres occurred in 1829. Light surface fires and crown fires were infrequent. The majority of the fires were of a moderate to high intensity and probably burned most of their acreage late in the growing season to Fall. According to District Timber Management personnel the growing season in the Caribou probably ends in mid August (Welles and Tuma, personal communication). Commercial forest areas adjacent to the Caribou Wilderness in the Silver Lake area have had extensive stand examinations over the past few years. The age of layer one trees are uniform over large areas suggesting one or more stand replacing fires circa 1780. A detailed examination of the stand age information has not been started yet.

Suppression era fires have been small. Since 1905 only one fire has burned more than ten acres -- 138 acres in 1929. Fires average 2.2 lightning caused and 0.1 human caused per year. Fires are usually expressed as a per 10,000 acre basis. These figures result in a fire occurrence rate of 1.14 lightning and .06 human per year per 10,000 acres in the Caribou Wilderness. This compares to 0.63 lightning caused and 0.37 human caused fires per 10,000 acres for the remainder of the Almanor District.

Adjacent Lassen Volcanic National Park has a similar suppression era fire occurrence, however a fire in 1987 burned 400 acres near Snag Lake, during a time of drought, multiple other fires, and suppression resources shortage. A human caused fire near Butte Lake burned 3 acres in 1988. Under very unusual circumstances, a lightning fire smoldered for two months before being detected in 1995. It was managed as a PNF for 118 days from September 17 to its natural extinguishment at approximately 7 acres. A lightning caused fire burned 35 acres on the boundary between LVNP and Lassen National Forest near Sunrise Peak, extreme northwest corner of the Wilderness, in 1992.

Visitor Use

The Wilderness trail system has three trailheads: Cone Lake in the north, Caribou Lake in the east, and Hay Meadow in the south. Hay Meadows and Caribou Lake trailheads experience the most use. One connector trail runs between Triangle Lake and the Lassen Volcanic National Park trail system near Butte Lake. (Map 1)

During the last three years (1993-1995) Recreation Visitor Days (RVD) have averaged 8,800 per year, with 1995 as lower than the other years due to a heavy snow year. The trails did not open until mid July. Other years have had visitor use as high as 14,000. Weekends account for 66% of use.

The use figures were provided by Lisa Sedlacek, Almanor District Wilderness Technician. The Values per RVD are from the 1990 RPA Program, adjusted to 1995 values.

Data collected Aug. 15 to Oct. 30, 1995 from visitor registry stations at each trailhead.

Use			Value per RVD	Total Value
Backpacking	36%	2607	$13.59	$35,429.13
Day Hiking	34%	2462	13.59	33,458.58
Swimming	14%	1014	10.10	10,241.40
Fishing	10%	724	15.22	11,019.28
Horseback Riding	3%	217	13.59	2,949.03
Other	3%	217	11.34	2,460.78
Total		7,241		$95,558.22

Visitor Location:

Local	46%	Southern Ca.	3%
Bay Area	25%	Northern Ca.	4% (other than previously mentioned)
Sacramento	16%		
Out of State	5%	Foreign	1%

Table 1
Recreation Use

The most heavily used areas are the large lakes: Long Lake, Triangle Lake, Beauty Lake, and Posey Lake. However, almost every lake of more than a few acres in size and along a trail receives use. Prescribed Natural Fires in the Caribou could disrupt visitor use if the fire spread to one of the trails or large lakes and the area was closed due to public safety.

The Lassen National Forest NFMAS model uses the following Net Value Changes in the High Wilderness Analysis Zone:

Net Value Change
High Wilderness Analysis Zone

Fire Intensity Level	Flame Length	NVC per Acre
1	0 - 2 feet	$253.96
2	2 - 4 feet	533.14
3	> 4 feet	585.00

Values from 1994 NFMAS Analysis, Lassen National Forest.

Weather

Lassen National Forest does not have a weather station that specifically represents the Caribou Wilderness. The two stations most commonly used for the Caribou Wilderness are Bogard (station number 040703) and Almanor (040904). Solem (1995) used data from the National Weather Service data from Chester to model temperature and precipitation in the Caribou Wilderness. Other times Bogard is used (Rick Addy, Forest Dispatcher, personal communication). Other stations exist but are not representative of the area or have incomplete data. A new RAWS station was established during 1995 near Hat Mountain, almost in the geographic center of Lassen Volcanic National Park. Data from this station was intermittent and unreliable until technical problems were corrected late in the year. When fully operational it may accurately represent the Caribou Wilderness.

A portable RAWS (040998) unit was positioned at Silver Lake, near the wilderness edge, from July 27 to October 1, 1995. Weather data from the 67 days was compared to the weather for the identical dates from Almanor and Bogard. The null hypothesis that the weather at Silver Lake is no different from the weather at either Bogard or Almanor ($H_0 = (\mu_1-\mu_2=\delta)$ where $\delta = 0$ or no difference and $\alpha=.05$) was established. Using the test for the difference between means:

$$z = \frac{\bar{x}_1-\bar{x}_2-\delta}{\sqrt{\frac{\sigma_1^2}{n_1}+\frac{\sigma_2^2}{n_2}}}$$

figure 1

with sample 1 = Bogard or Almanor and sample 2 = Silver Lake and converting the z to a probability the following values were obtained:

	Bogard	Almanor
1400 Temperature	0.002	0.00
1400 Relative Humidity	0.11	0.012
1400 Fuel Stick	0.00	0.00
Maximum Temperature	0.15	0.00
Minimum Temperature	0.00	0.30
Maximum Relative Humidity	0.00	0.62
Minimum Relative Humidity	0.70	0.00
Wind Speed[1]	0.33	0.00
Wind Direction	0.00	0.00

Table 2

Probability of Similar Weather between Silver Lake and either Almanor or Bogard

The Almanor and Bogard wind data are 20 foot wind speeds, while the Silver Lake data is mid-flame. To make the wind speeds the same the wind reduction technique outlined by Rothermal (1983) using the fully sheltered open stand factor of .20 and a locally derived factor of .35[1] were used.

The null hypothesis is rejected in five of the nine categories for Bogard and seven of the nine for Almanor. Not all categories are of equal importance in influencing fire behavior but no relative weighting was used. From the number of rejects versus number of accepts the conclusion was made the weather at Silver Lake, (and thus the Caribou Wilderness) cannot be represented by the historic weather data from either Almanor or Bogard.

[1] A site specific wind reduction factor of .35 was obtained by dividing the average wind speed at Silver Lake by the average wind speed at Bogard. The same factor was obtained using Almanor data

To develop a data base of historical weather for the Caribou Wilderness the Silver Lake weather observations were compared to the Almanor and Bogard observations to measure the relationship between the individual weather stations. A series of regressions was performed using a shareware program called Curvefit and the resulting R^2 values were compared. In every case except wind speed the best fit was a linear model.

	Silver Lake versus:	
	Bogard	Almanor
1400 Temperature	.912	.928
1400 Relative Humidity	.689	.694
1400 Fuel Stick	.707	.669
Maximum Temperature	.769	.921
Minimum Temperature	.412	.669
Maximum Relative Humidity	.002	.329
Minimum Relative Humidity	.696	.666
Wind Speed	.101	.224
Wind Direction	.005	.015

Table 3
R^2 Values between Silver Lake and either Almanor or Bogard

The low fit between Bogard and Silver Lake minimum temperature and maximum humidity is probably explained by topography. Bogard experienced several nights of 100% humidity recovery as expected in a valley bottom. Silver Lake is drained by the Susan River and would not experience as many inversions.

Outliers from each of the regressions were noted. A common date among the Bogard outliers was August 22, 1995. On this date Bogard had a state of weather of three (overcast) while Almanor was zero (less than one tenth cloud cover). This would account for large differences in the fuel stick and 1400 relative humidity between Bogard and Silver Lake. Disregard that single outlier (Aug. 22) and the R^2 of Bogard Relative Humidity is .823. All outliers were retained, though, to avoid biasing the data, and because differences in cloud cover can be expected between two weather stations on any given day.

Wind speed and direction also showed a low fit, but these factors are highly influenced by local topography and vegetation cover. The wind speed was adjusted using the same techniques noted above. As expected, these yielded no better results.

Wind direction yielded no discernible correlation. The data is given in degrees. After no correlation the cosine of the direction was used with equally poor results. A histogram of the Silver Lake wind direction is bimodal with modes at 100 degrees and 300 degrees, or roughly east and northwest. The specific site of the Silver Lake RAWS unit was along the west shore of the lake. This site is approximately 1.5 miles northeast of the Caribou Peaks. The Caribou peaks at an elevation of 7800 feet would effectively shelter the Silver Lake RAWS unit from the predominate southwest flow over the area, explaining the unusual wind directions. Because of localized topographic and vegetation effects any estimation of wind speed or direction in the Wilderness should use the techniques taught in S-490 Advanced Fire Behavior or similar classes.

The R^2 values for Almanor exceed those of Bogard in five of the seven observations (excluding wind speed and direction). The two observations where Bogard had a higher R^2 are the fuel stick and minimum relative humidity. These were larger by .038 and .030 respectively -- a relatively small value. From the comparison of the above R^2 values the conclusion is reached that Almanor weather data should be used as the basis of estimating weather in the Caribou Wilderness.

No precipitation was recorded at any of the three weather stations during the sample period. Extrapolations done by USGS (1969) and California Dept. of Water Resources (1976) were used to estimate the annual precipitation in the Caribou Wilderness. Near the perimeter of the prescribed Natural Fire Zone the annual precipitation is 54 inches in the northern half and 62 inches in the southern half. (Map 4) Chester averages 34 inches per annum. The ratio between Chester and the two Caribou rainfall amounts may be used as an approximation of the precipitation amount on any given day for general area-wide storms, but not localized thunderstorms. This method will not be accurate for any specific date but is a reasonable method of estimating rainfall in the absence of more accurate data (Steve Young, Forest Hydrologist, Lassen National Forest, personal communication.) Using the above precipitation figures yields 54/34 or 1.588 and 62/34 or 1.824. Multiplying these ratios times the Fall, Winter and Spring precipitation for Chester will estimate precipitation amount. I used smaller factor, 1.588, to represent the Caribou Wilderness weather. The larger factor would result in lower indices and an earlier date of a fire ending event than otherwise would occur. Precipitation from June 15 to Sept. 15 were assumed to be mostly localized thunderstorms and not subject to the orographic differences, so the factors were not applied to this time span. Rainfall duration is assumed to remain the same.

Assuming there is no appreciable difference in localized rainfall amounts due to a summer thunderstorm, the difference in precipitation is largely in the Fall, Winter, and Spring area-wide storms. This would indicate an approximately six to eight foot deeper snowpack in the south half of the Wilderness than the north. (Jules Riley, Almanor District Hydrologist, personal communication.) The effect of the deeper snowpack on green-up date and the seasonal live fuel moisture gradient has not been determined, but it may be assumed some effect occurs. This is indicated by the larger amount of surface water and streams and a greater proportion of mesic ground cover in the southern half.

Historical weather data for the Caribou Wilderness is needed to define a fire ending event. Weather data from 1970 to 1974 from the Almanor weather station was read into a spreadsheet and each column was converted to representative Caribou weather by using the regression equations obtained above. For unknown reasons 1971 data was missing.

State of Weather	Unchanged
1400 Temp	Silv = -10.01 + 1.02*Alm
1400 Relative Humidity	Silv = 4.007 + 0.9864*Alm
1400 Fuel Stick	Silv = 2.068 + 0.764*Alm
Maximum Temp	Silv = -0.303 + 0.895*Alm
Minimum Temp	Silv = 2.58 + 0.963*Alm
Maximum Relative Humidity	Silv = 29.58 + 0.554*Alm
Minimum Relative Humidity	Silv = 8.335 + 0.8814*Alm
Wind Speed	Unchanged
Wind Direction	Unchanged
Precipitation Amount	Alm * 1.588 (Sept. 16 through June 14 only)
Precipitation Duration	Unchanged

Table 4
Relationship of Silver Lake weather to Almanor weather

The modified data was then used as representative weather data for the Caribou Wilderness. Before 1990 the Almanor weather station was a manual station. The data was not gathered every day nor year long. During the years 1970 to 1994 the daily weather observations ceased at the end of the declared fire season, usually in early October. Consequentially, an incomplete data base for the critical Fall season exists. From 1990 to present the station has daily year round observations.

National Fire Danger Rating System (NFDRS) indices were calculated using the PCFIRDAT program with the following parameters:

1988 NFDRS	
Fuel model	G
Slope	1
Herbaceous	Perennial
Shrub	Deciduous
Climate	3
1 hr = 10 hr	
Green up	June 15
First Frost	Oct. 10